ACE MEETING, June 22, 2004

- Tevatron Status
  - Tevatron continues to start stores with high initial luminosities as high as 90E30.! Proton losses however continue to be major problem at beginning of stores. Abort gap losses are under review as new sync light monitor is commissioned. (Ron and/or Rainer may say more...)
  - Continue to "stack and store" with shots about every 30-36 hours. We need an access to work on CMX HV.

- Miscellaneous Ace Items
  - Be proactive - SciCo and/or Ops Manager will not always remember to tell you to put voltages in correct state. Remember we don't have wire chambers on when Tevatron is being tuned up with beam. COT is OFF unless we have collisions.
  - New feature allows DAQ ACE to send "yellow pop-up box" directly to eLog. We don't need to paste every box into eLog. Any suggestions on guidance?

- Accelerator Basics - Ron Moore

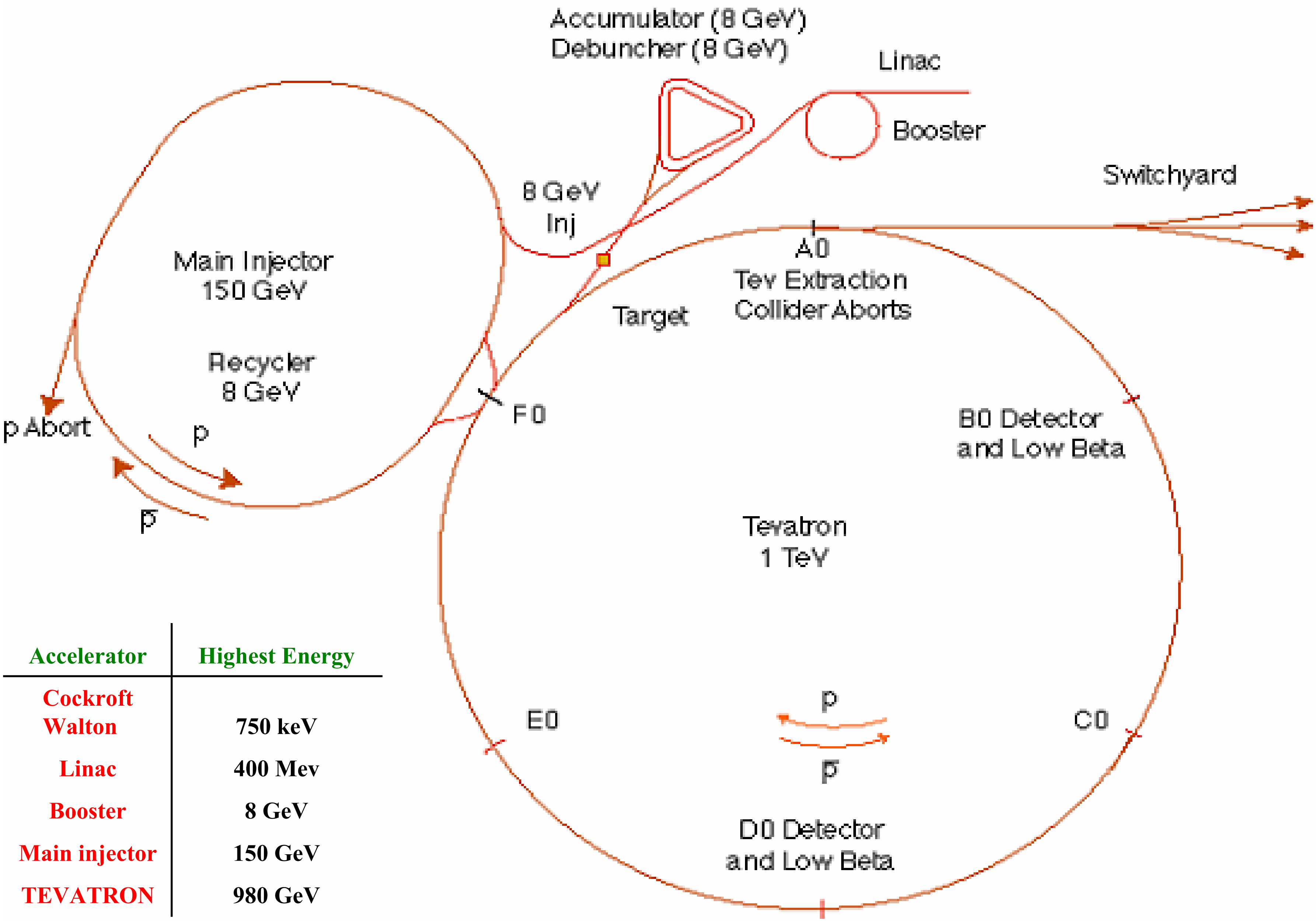
- Silicon Review - Rainer Wallny

FNAL Accelerator Complex 101: What's Happening in the Machines?

Ron Moore – FNAL

- Accelerator Complex Overview
- Shot-Setup
- Miscellany

FermilabTevatron Accelerator With Main Injector



Accelerator	Highest Energy
Cockroft Walton	750 keV
Linac	400 Mev
Booster	8 GeV
Main injector	150 GeV
TEVATRON	980 GeV

Proton Source

- 25 keV H^- ion source
- 750 keV Cockcroft-Walton accelerator

- Linac: accelerate H^- ions to 400 MeV
  – 116 MeV Alvarez linac (201.25MHz)
  – 400 MeV side-coupled cavity linac (805 MHz)

- Booster: 8 GeV synchrotron
  – Runs at 15 Hz
  – Stripper foil at injection removes electrons from H^- ions
  – Accelerates protons from 400 MeV to 8 GeV
  – Most protons (>75%) going through Booster are delivered to MiniBoone

Main Injector (MI)

- Replaced Main Ring (formerly in Tev tunnel)
  - Higher repetition rate for stacking pbars
  - Simultaneous stacking and fixed target running
- Many operating modes
  - Pbar production: ~ $5*10^{12}$ 120 GeV protons to pbar target
  - Tevatron protons/pbars:
    - Accelerate 8 GeV to 150 GeV
    - Coalesce 7-9 proton bunches 90% eff into 270-300 E9 bunch
    - Coalesce 7-11 pbar bunches 75-90% eff into 20-40 E9 bunch
  - Transfer 8 GeV protons/pbars to the Recycler
  - Provide protons for neutrino production
    - 8 GeV protons for MiniBoone
    - 120 GeV protons for NuMI (eventually)
  - 120 GeV protons to Switchyard (fixed target area)

Pbar Source

- > $5*10^{12}$ protons per pulse (120 GeV) strike Ni target every 2-3 sec
- Li lens (740 Tesla/m) collects negative secondaries
- Pulsed dipole bends pbars down AP-2 transfer line toward Debuncher, Accumulator
- Stack rate = 6-13 mA/hr depending on stack size
  - Limited by stochastic cooling systems in Accumulator
  - Hope to reach 18 mA/hr this fiscal year
- Efficiency ≈ $(13\text{-}18)*10^{-6}$ pbars/proton on target
- Transverse beam size increases linearly with stack size

Recycler (RR)

- Fixed energy (8 GeV), permanent magnet storage ring in MI tunnel
- Still being commissioned
- Originally supposed to “recycle” pbars left over from a Tevatron store
- Now will only be used as intermediate pbar storage ring
  - Build small stack in Accumulator, transfer to Recycler; repeat…
  - Take advantage of high Accumulator stacking rates for small stacks

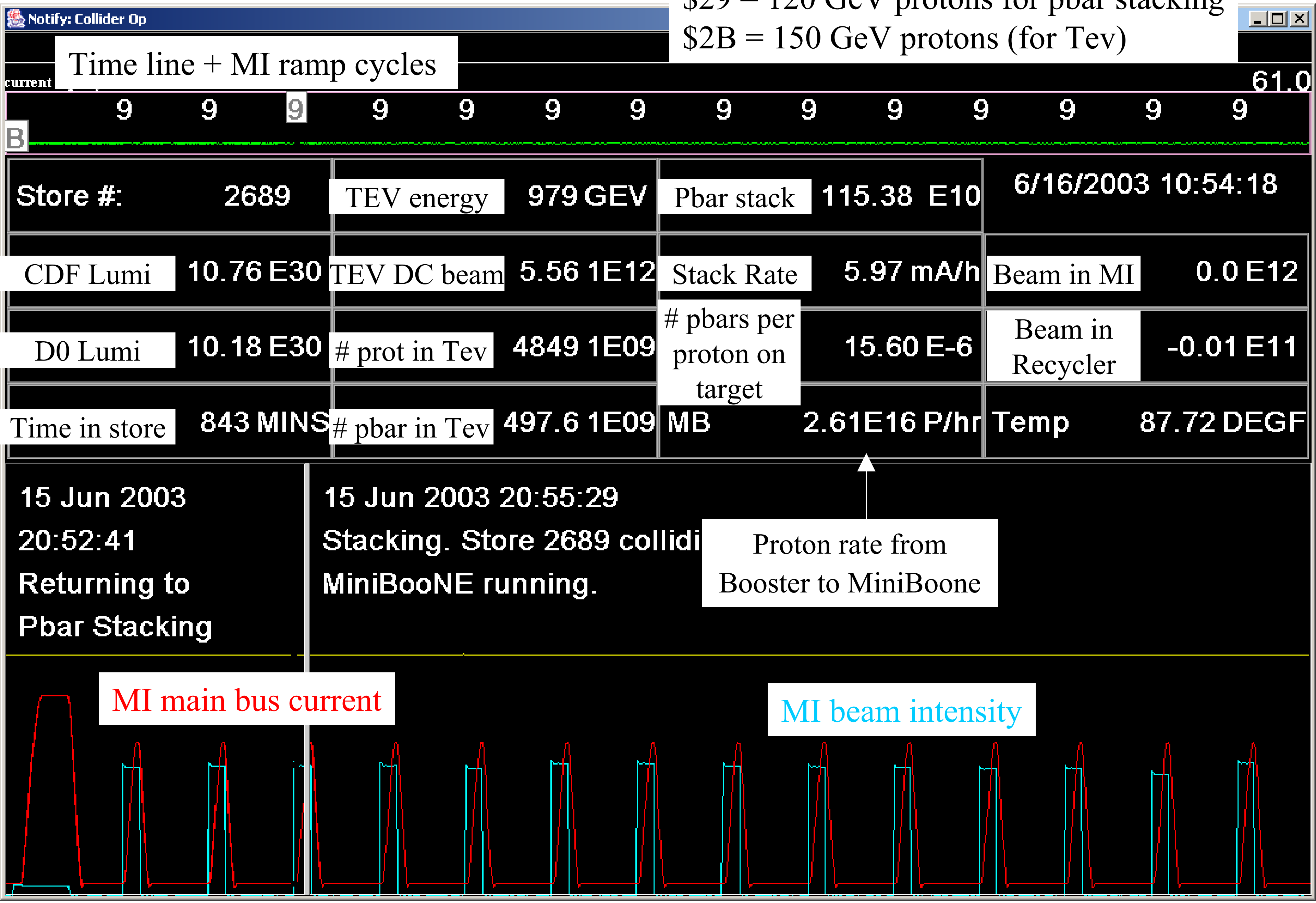
- Eventually, pbars for HEP stores will be shot from Recycler

Tevatron Overview

- Provides proton-pbar collisions @ 980 GeV beam energy
- Injection energy is 150 GeV
  - Protons injected from P1 line at F17
  - Pbars injected from A1 line at E48
- 36 bunches of proton and pbars circulate in same beampipe
  - Electrostatic separators keep beams apart
- 3 trains of 12 bunches with 396 ns separation
- Tevatron radius = 1 km $\Rightarrow$ revolution time ~ 21 μs
- Virtually all of the Tevatron magnets are superconducting
  - Cooled by liquid helium, operate at 4 K
- 2 low β (small beam size) intersection points (CDF and D0)
- 1113 RF buckets (53.1 MHz $\Rightarrow$ 18.8 ns bucket length)

Channel 13, a.k.a “Notify”

Channel 13 with help



Glossary

- **Stack** = antiprotons being stored in the Accumulator or Recycler
- **Store** = beam kept circulating continuously in the Tevatron; can be an HEP store (protons and pbars), or proton-only for studies/maintenance
- **Ramp** = accelerating beam from 150 GeV to 980 GeV (in Tev), dipole magnet current increasing to bend beam harder as energy rises
- **Flattop** = Tev ramped to 980 GeV, **before** low β squeeze
- **Squeeze** = Focusing the beams to smaller transverse size at CDF/D0
- **Low Beta** = Tev @ 980 GeV, **after** low β squeeze
- **Initiate Collisions** = turn on electrostatic separators to make beams collide at the centers of CDF and D0
- **Scraping** = Removal of beam "halo" (stuff far away from beam center) by moving stainless steel collimators close to beam; reduces beam losses at CDF/D0; done automatically after collisions begin; takes 12-15 minutes
- **Cogging** = moving the (pbar) beam longitudinally desired location
- **Abort Gaps** = series of empty buckets between bunch trains to allow abort kickers to reach proper voltage to kick beam into dump blocks

Glossary

- **FBI** = Fast Bunch Integrator
  - Provides Tev bunch intensity measurements
- **SBD** = Sampled Bunch Display
  - Gives Tev bunch length and intensity measurements
- **DC Beam** = beam not captured in an RF bucket
  - Can circulate around for minutes before losing energy via synchrotron radiation and striking an aperture (collimator)
- **TEL** = Tevatron Electron Lens
  - Device that shoots a ~few mA electron beam in the Tev beam pipe
  - Used to knock beam out of the abort gaps (reducing CDF backgrounds)
  - Intended to compensate beam-beam tune shift of pbars from protons (not yet)
- **SDA** = Shot Data Acquisition
  - Accelerator data collection/storage for each shot/store; used for offline analysis
- **QPM** = Quench Protection Monitor
- **QBS** = Quench Bypass Switch

Prior to Shot-Setup

- Run Coordinator decides when to end store (usually pbar stack > 100 mA)
- Experiments turn off HV after MCR calls
- Experiments call MCR to confirm they are ready
- Tev abort kickers fire driving beam into A0 dump blocks

- Tev unsqueezes, ramps down to 150 GeV
- Tev ramps to 980 GeV, squeezes, sits at low β for 20 min
  - "Dry squeeze" $\Rightarrow$ no beam (good time for calibrations)
  - Resets magnet fields to "known" condition
  - Sometimes "wet squeeze" (uncoalesced beam) to gather orbit data
- Tev unsqueezes, ramps down to 150 GeV, begin shot-setup with beam

- ~30 minutes minimum without beam in Tevatron after store ends

- Meanwhile, pbar starts "cooling" the stack, then change Accumulator to "shot lattice" in preparation for shot-setup

Shot Setup Overview

- MCR crew performs beam line tune-up for Pbar, Main Injector, and Tevatron
  - Make sure extracted beams are injected into next machine on, or very close to, desired orbit
  - Helps reduce oscillations that cause emittance (size) growth

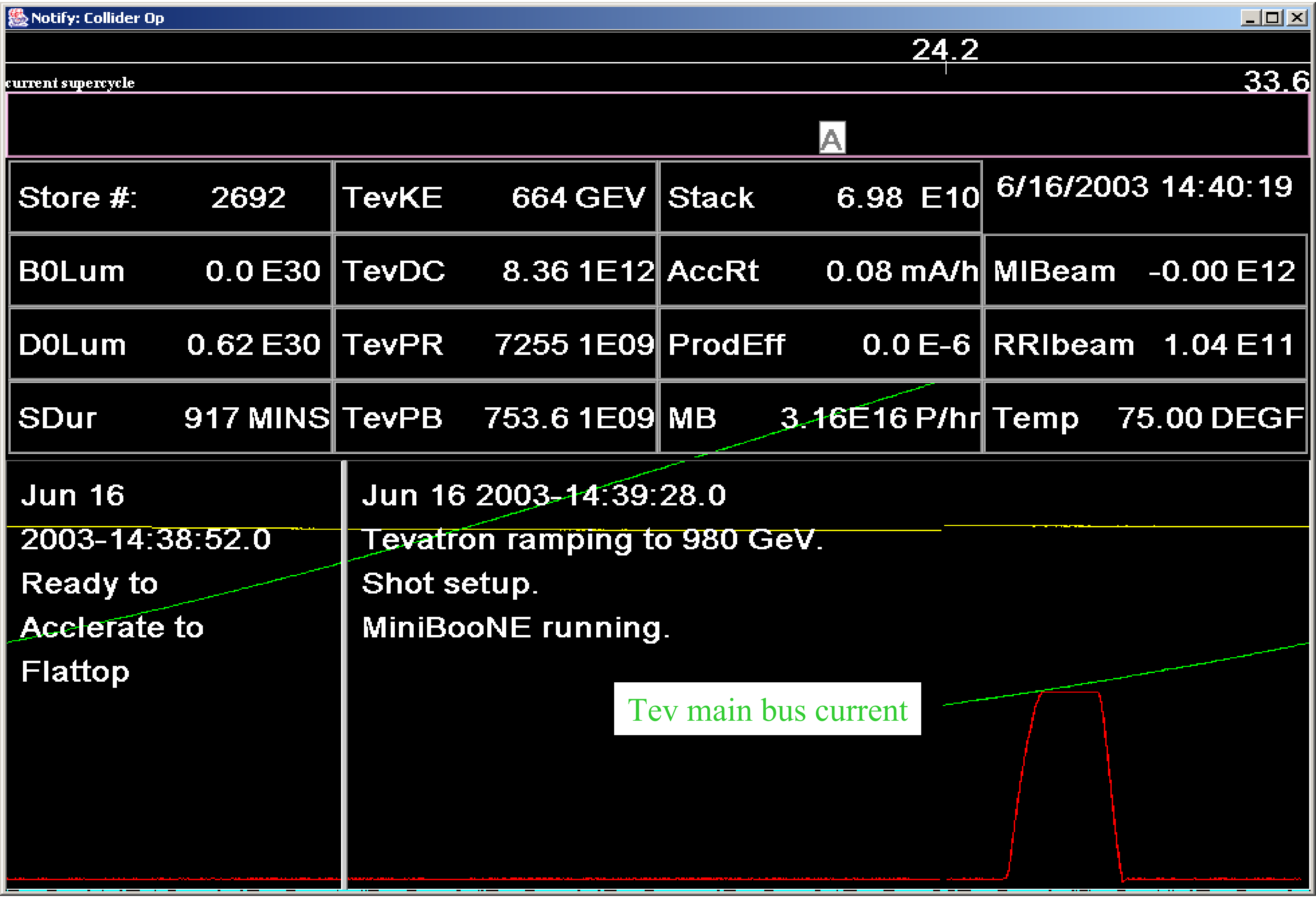
- MCR crew also sets Tevatron tune, chromaticity, coupling to desired values @ 150 GeV
  - Important for beam lifetimes

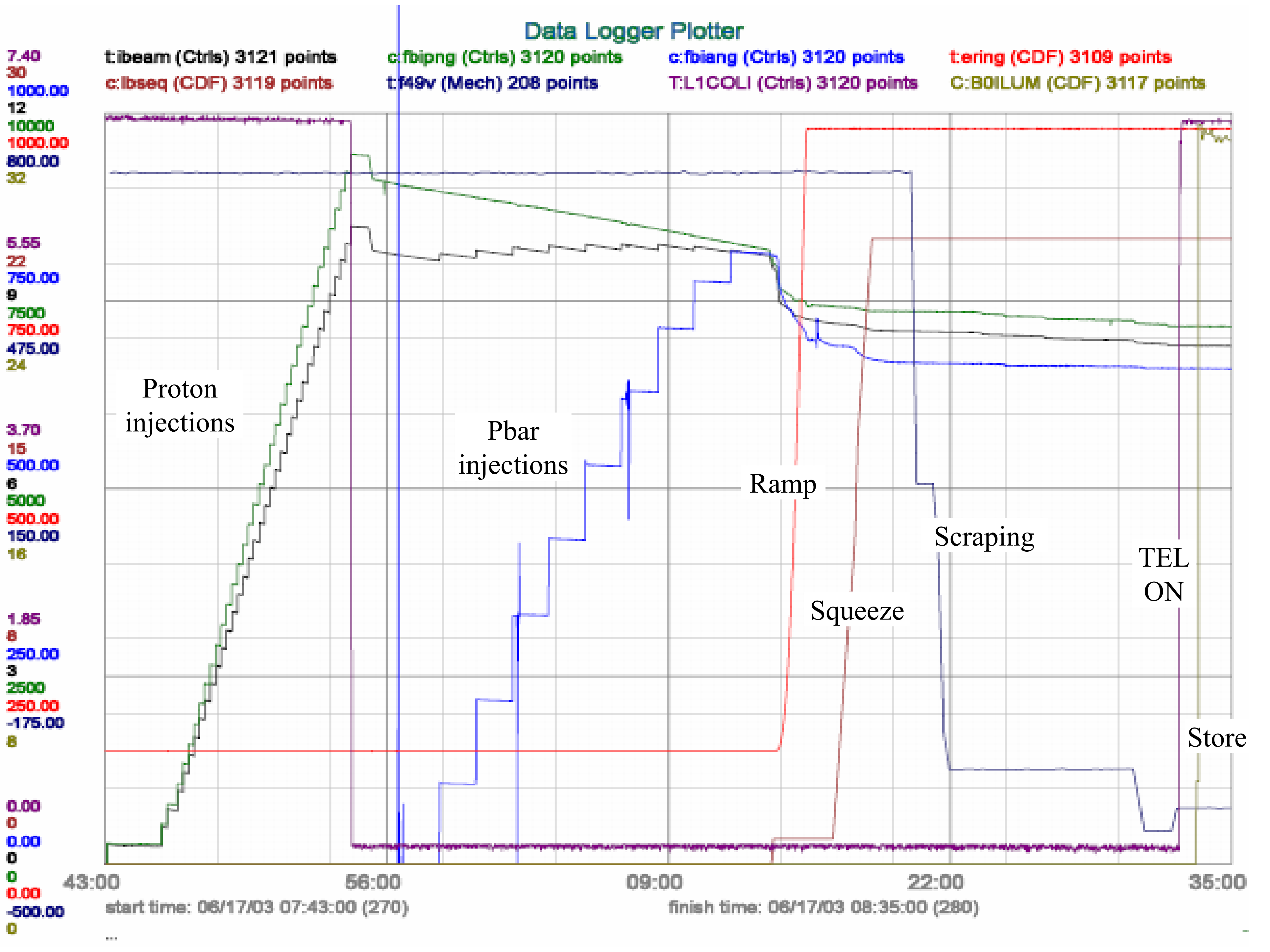
- Shots can begin once all the machine and beam-line tune-ups are complete.

Shots to the Tevatron

- Protons are injected first (onto central orbit) 1 bunch at a time
- Separators turned on to put protons on helical orbit
- Pbars are injected 4 bunches at a time into abort gaps
  - After 3rd and 6th pbar transfers, pbars cogged to empty the gaps
- Accelerate beams to 980 GeV (~90 sec)
- Final pbar cogging to collision position
- Low Beta Squeeze (~ 2 minutes)
- Initiate Collisions (change separator voltage around IPs)
- Scraping (~12-15 minutes)
- Turn on TEL
- MCR declares store ready for HEP
- Typical time from store end to start of new store: 2-3 hours
- Once losses are low and beam is stable, ramp the HV and begin taking data

Channel 13 while Tev is ramping





Data Logger Plotter
t:ibeam (Ctrls) 3121 points
c:fbipng (Ctrls) 3120 points
c:fbiang (Ctrls) 3120 points
t:ering (CDF) 3109 points
c:lbseq (CDF) 3119 points
t:f49v (Mech) 208 points
T:L1COLI (Ctrls) 3120 points
C:B0ILUM (CDF) 3117 points
7.40
30
1000.00
12
10000
1000.00
800.00
32
5.55
22
750.00
9
7500
750.00
475.00
24
3.70
15
500.00
6
5000
500.00
150.00
16
1.85
8
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2500
250.00
-175.00
8
0.00
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0.00
0
0
0.00
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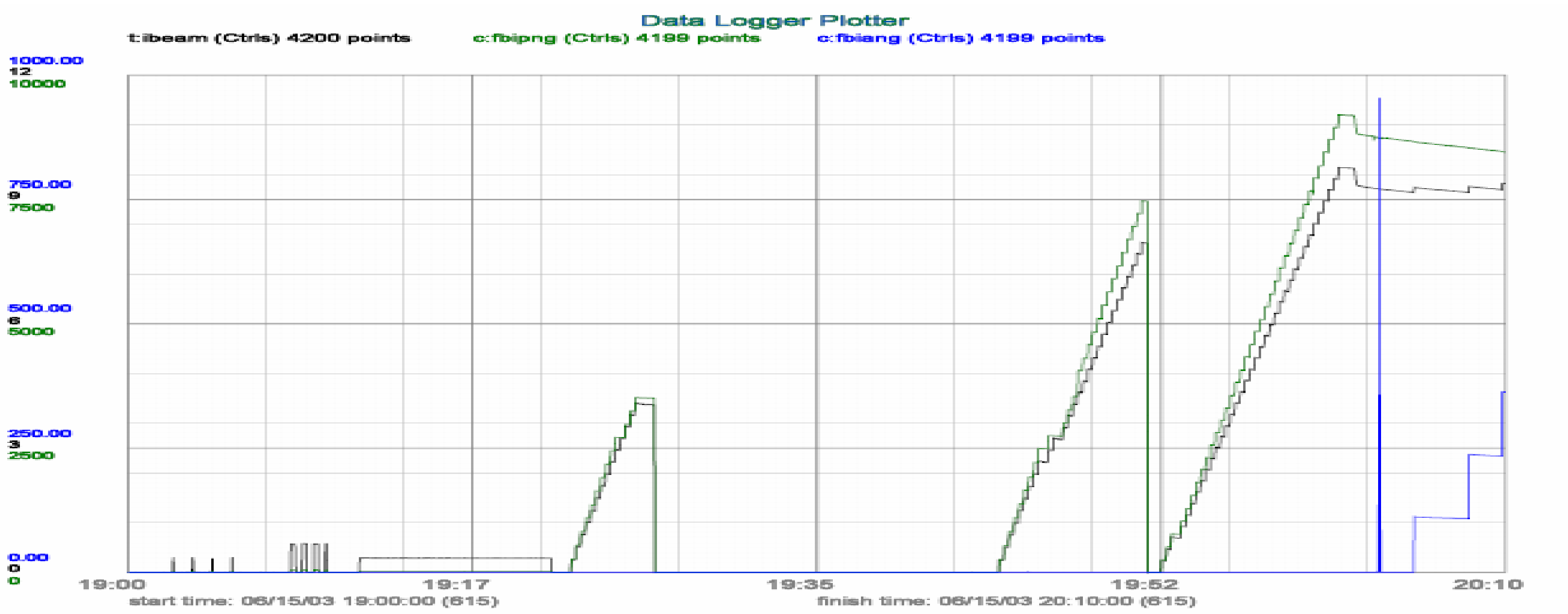
43:00
56:00
09:00
22:00
35:00
start time: 06/17/03 07:43:00 (270)
finish time: 06/17/03 08:35:00 (280)
Proton injections
Pbar injections
Ramp
Squeeze
Scraping
TEL ON
Store

While the Tevatron Has a Store…

- Pbar stacking begins after Tev scraping complete
  - 120 GeV proton pulses in P2 line could affect loss monitors used for feedback during scraping (P2 line in Tev tunnel)
- Protons delivered to MiniBoone
- Main Injector & Recycler studies can occur (as long their cycles don't occupy too much time in the time line)
- MCR crew monitors store, responds to CDF/D0 requests, e.g., reduce losses
  - A Tev expert always on-call to assist
- MCR crew also busy monitoring stacking, MiniBoone, helping studiers, fixing problems…they are vital to us all!

Injecting "Final" Protons

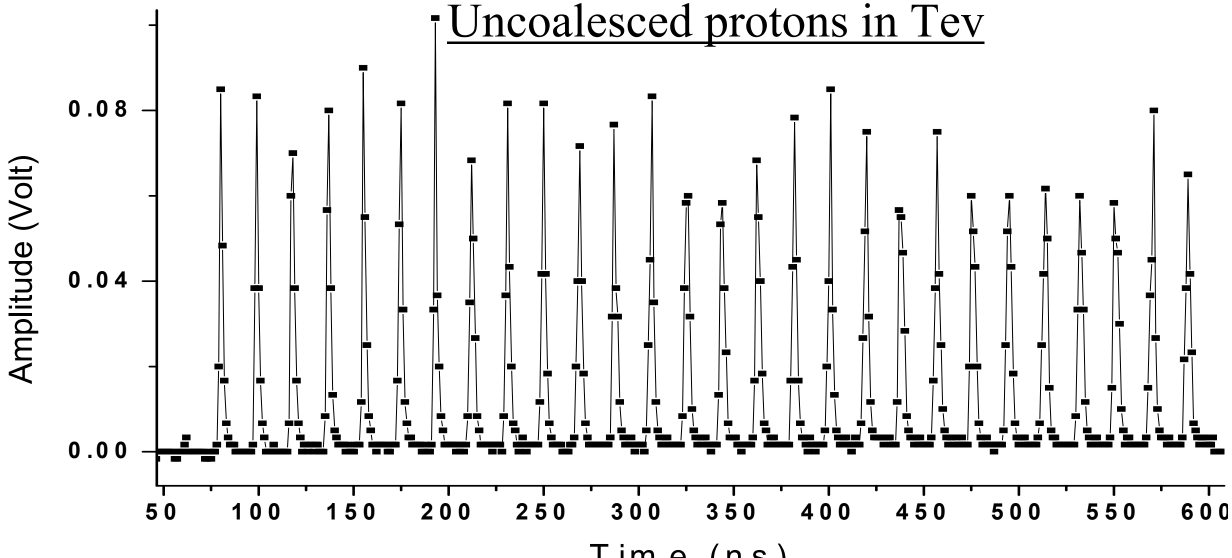
- Protons can be injected into Tev every 15 sec. (Limited by MI average magnet power.)
- Each proton bunch is "qualified" in the Main Injector.
  - If bunch below minimum intensity, it goes to MI dump, not the Tevatron
  - Purpose is consistency among the proton bunches
- While loading "final" protons, MCR often tunes on intensities, emittances
- If loaded protons don't have desired qualities, MCR may abort <u>intentionally</u>.
  - We seldom "lose" the injected protons during shot-setup.
  - Occasionally it may take 2 or 3 attempts to load protons as desired.



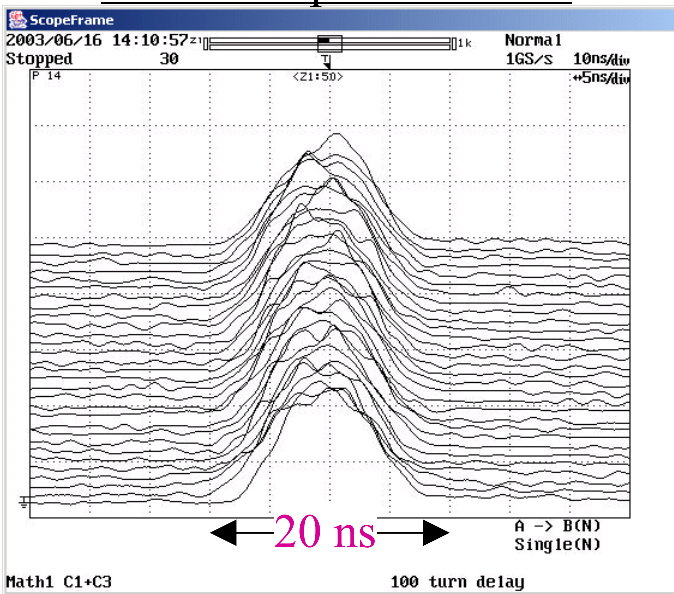
Coalesced vs Uncoalesced Beam

- Uncoalesced
  - 30 or so consecutive RF buckets filled with ~10 E9 protons/bunch
  - Usually used for machine tune-up, studies
  - Protons only (well, pbars can be uncoalesced if needed for some study)
- Coalesced
  - 5-7 buckets of beam merged into a single RF bucket at 150 GeV in MI
  - Protons and pbars always coalesced for HEP stores

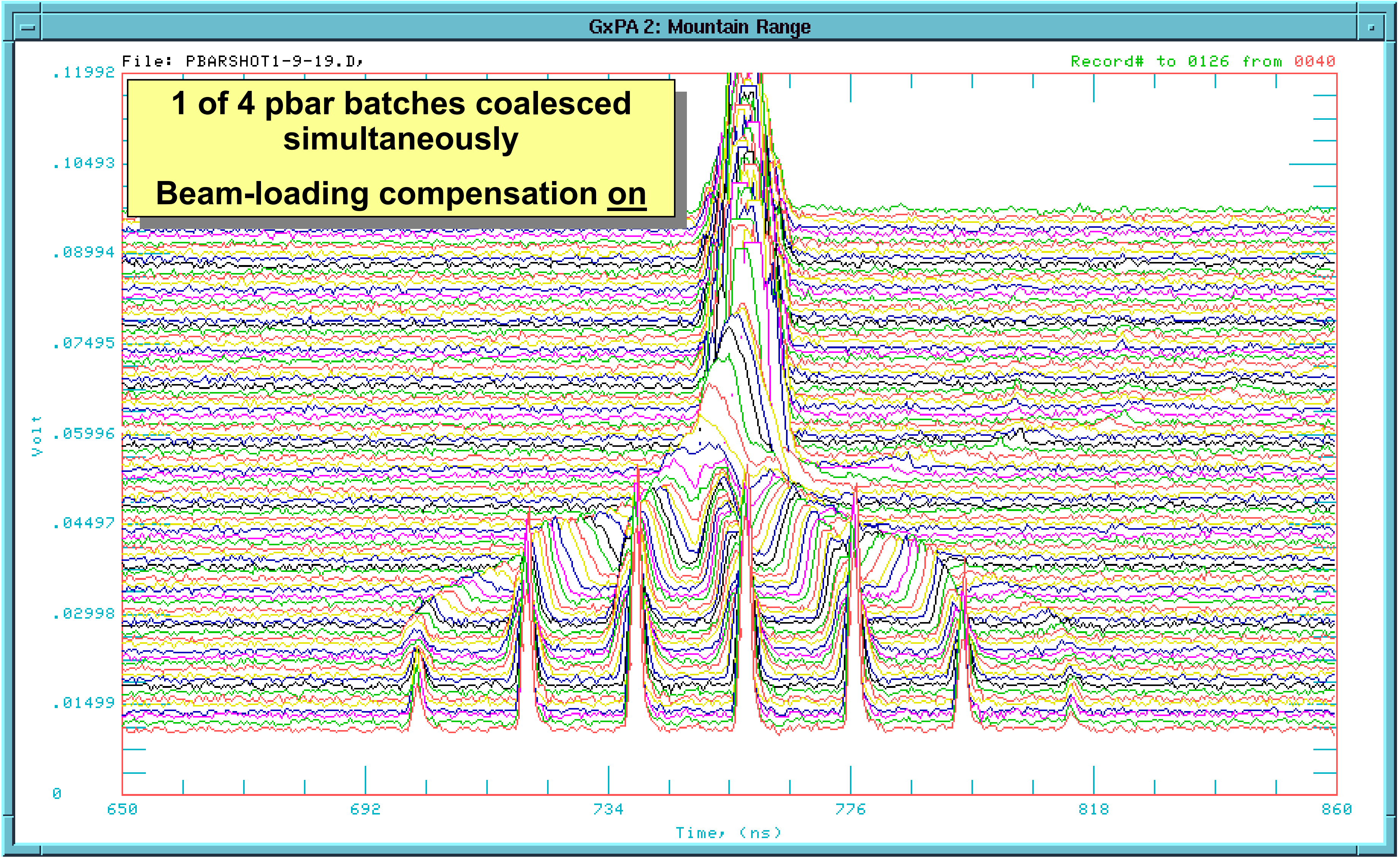
Uncoalesced protons in Tev



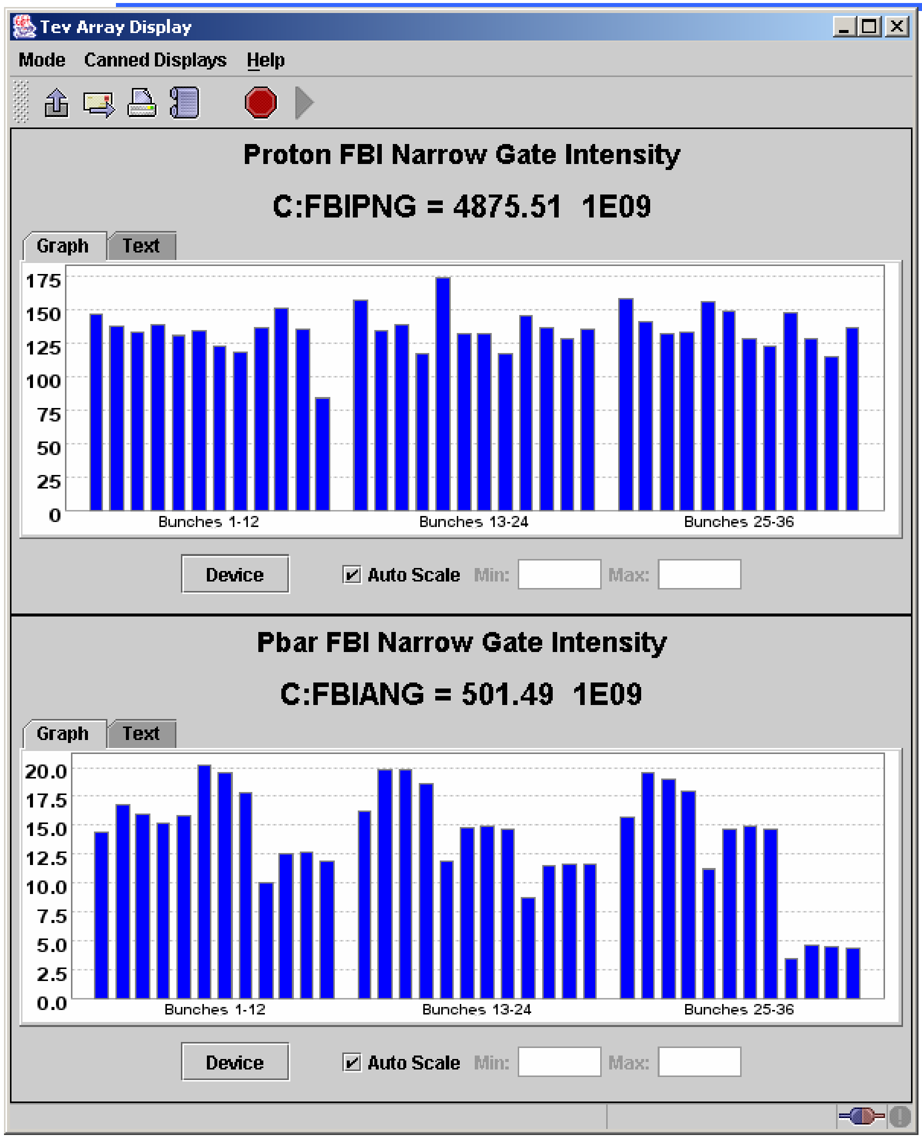
Coalesced proton in Tev



Pbar Coalescing in Main Injector

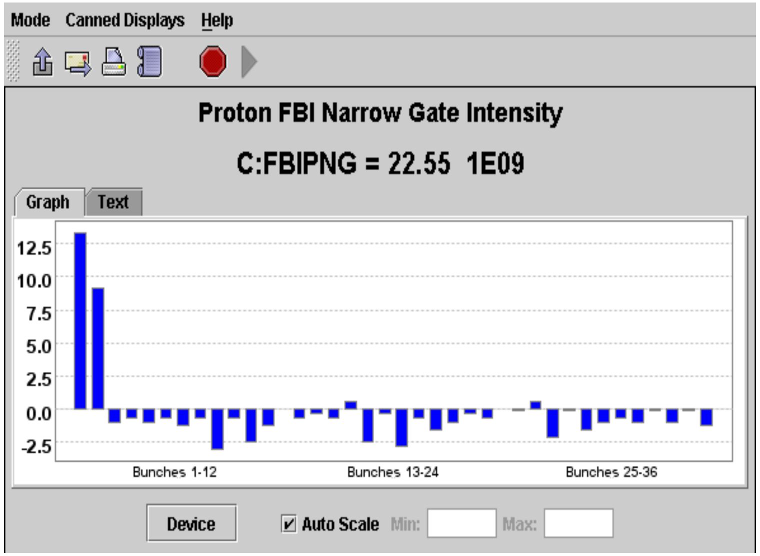


Tev Array Display

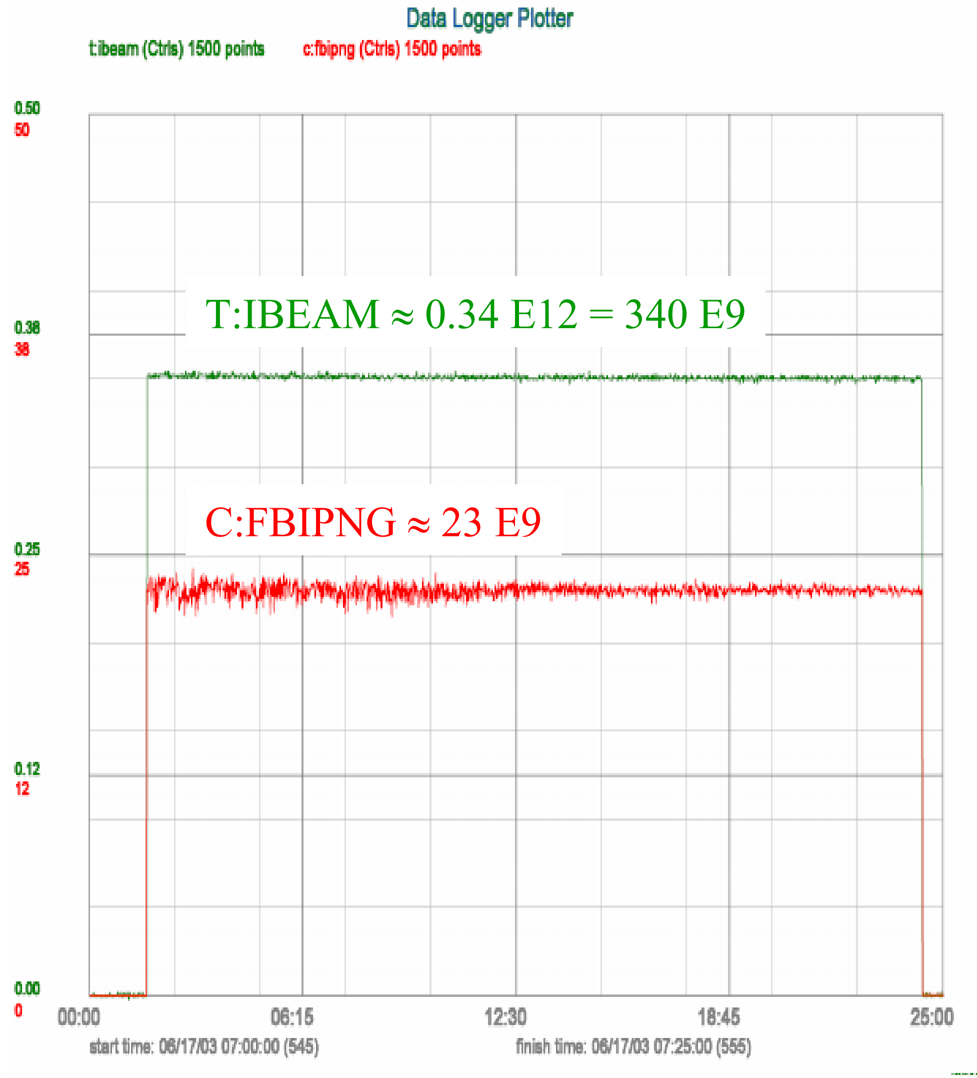


- Shows bunch-by-bunch parameters
- Usually running in CDF control room on Windows machine
- Useful during injection to see how many bunches are in the Tevatron

Two Little Bunches in the Tev?



- No, the FBI/SBD ACNET devices look only at buckets that should be populated with coalesced beam for HEP store
- 2 of the 30 bunches of uncoalesced protons happen to be in the buckets used for P1 & P2
- Compare T:IBEAM and C:FBIPNG



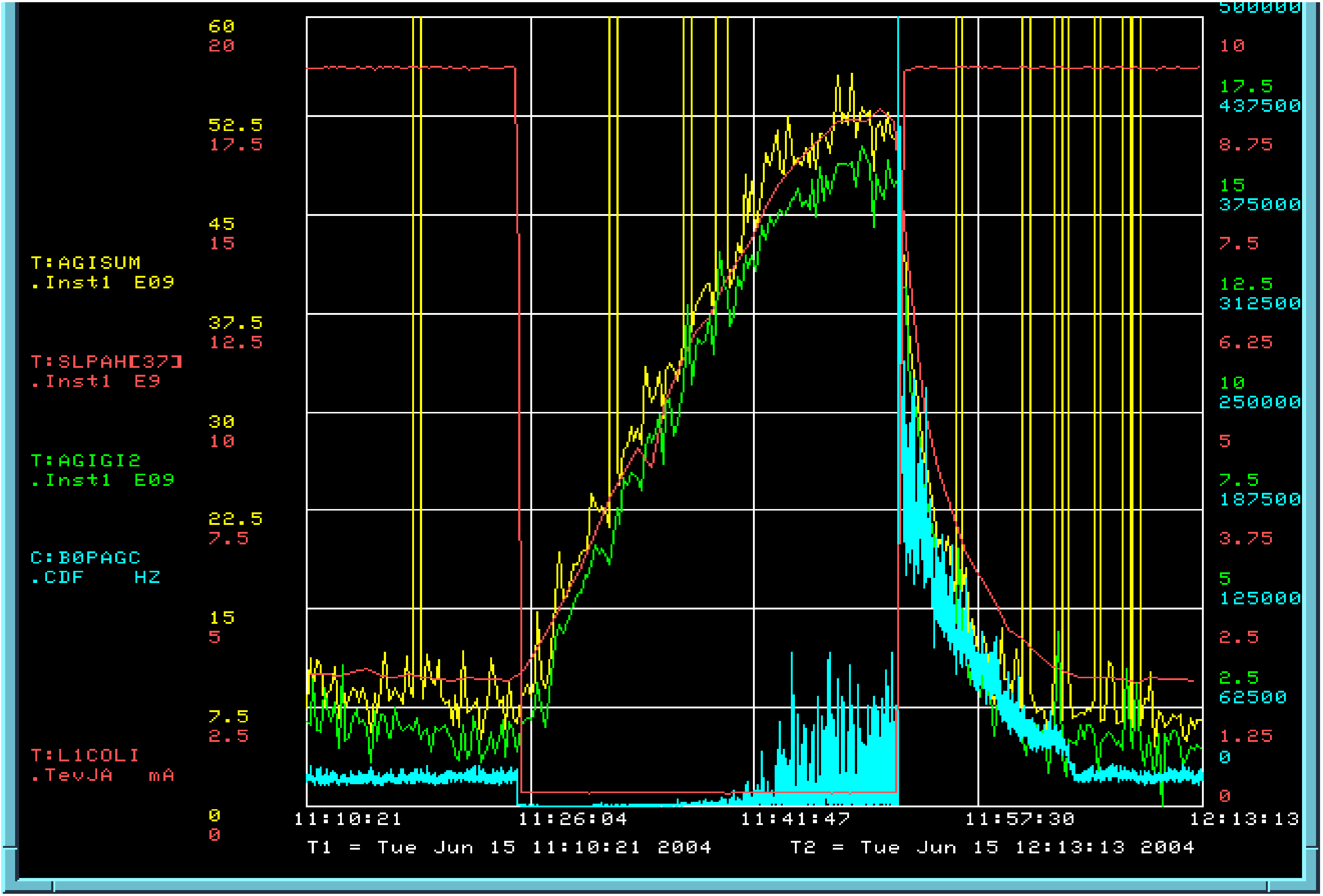
How can pbar stack be measured in mA?

- The revolution frequency of an 8 GeV particle in the Accumulator (not the Recycler) happens to be $\approx 1.6\ \mu s$
- $1.6\ (10)^{-19}$ Coulomb/pbar / $1.6\ (10)^{-6}$ s = $(10)^{-13}$ Amp/pbar
- $(10)^{10}$ pbars $\times$ $(10)^{-13}$ Amp/pbar = 1 mA!
- For pbars in the Accumulator: 1 mA = $(10)^{10}$ pbars

Abort Gap Monitors

- Until recently, scintillator paddles near CDF (C:B0PAGC) were the only means of estimating amount of DC beam in the abort gaps.
  - Not ideal – really only sees beam lost from the gap (TEL or otherwise) not absorbed by a collimator
  - Can vary even if real beam intensity in abort gap does not
- Now use synch light system to image directly beam in the gaps.
  - T:SLPAH[37] = uses the MCP (micro-channel plate) of the original synch light system
  - T:AGIGI1, T:AGIGI2, T:AGIG3, T:AGISUM = use a gated PMT to look at a beam of synch light split inside the synch light box
- Still commissioning the new synch light monitors, but we (MCR, Tev) want to use these beam intensities to determine safe levels of DC beam and how to reduce it if needed
  - Hope CDF will agree after gaining operational experience
  - > 5-7 E9 beam in gap will cause a quench when abort kickers fire

Testing Abort Gap Monitors



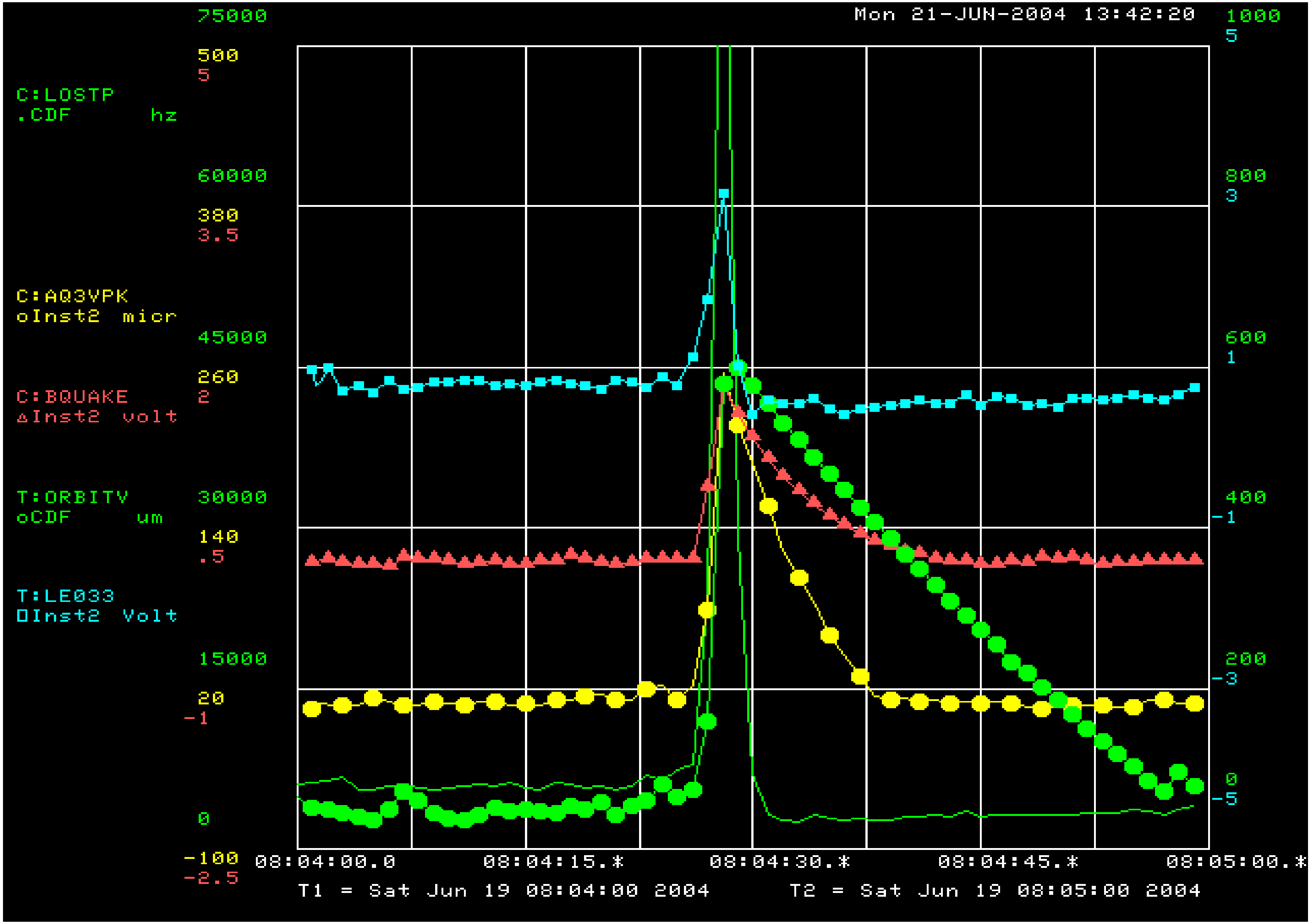
Trucks and C:LOSTP

- Yes, the CDF low beta quads are sensitive to surface traffic
  - We now know trucks on Ring Rd AND Road D can cause LOSTP spikes
- Quad motion imparts a kick to the beam that can drive it toward a collimator and cause a spike in losses
- C:BQUAKE = ground motion detector in the B0 service building
- C:AQ3VPK = tiltmeter/peak detector on A4Q3 quad in the CDF hall
- T:ORBITH/T:ORBITV = horz/vert "latched" orbit peak detectors

- Ideas to stiffen/damp the low beta quad girder hanging from the ceiling
  - D0 quads are supported from the floor

- We haven't had a real earthquake for a while…

Truck Quake!



Mon 21-JUN-2004 13:42:20
75000
500
5
C:LOSTP
.CDF hz
60000
380
3.5
C:AQ3VPK
oInst2 micr
45000
260
C:BQUAKE 2
ΔInst2 volt
T:ORBITV 30000
oCDF um
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.5
T:LE033
□Inst2 Volt
15000
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-100
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800
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400
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200
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0
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08:04:00.0
08:04:15.*
08:04:30.*
08:04:45.*
08:05:00.*
T1 = Sat Jun 19 08:04:00 2004
T2 = Sat Jun 19 08:05:00 2004

What You  should know about the Silicon

Ace Training recap II:

Oy veh, the Sili DAQ …

Say NO!

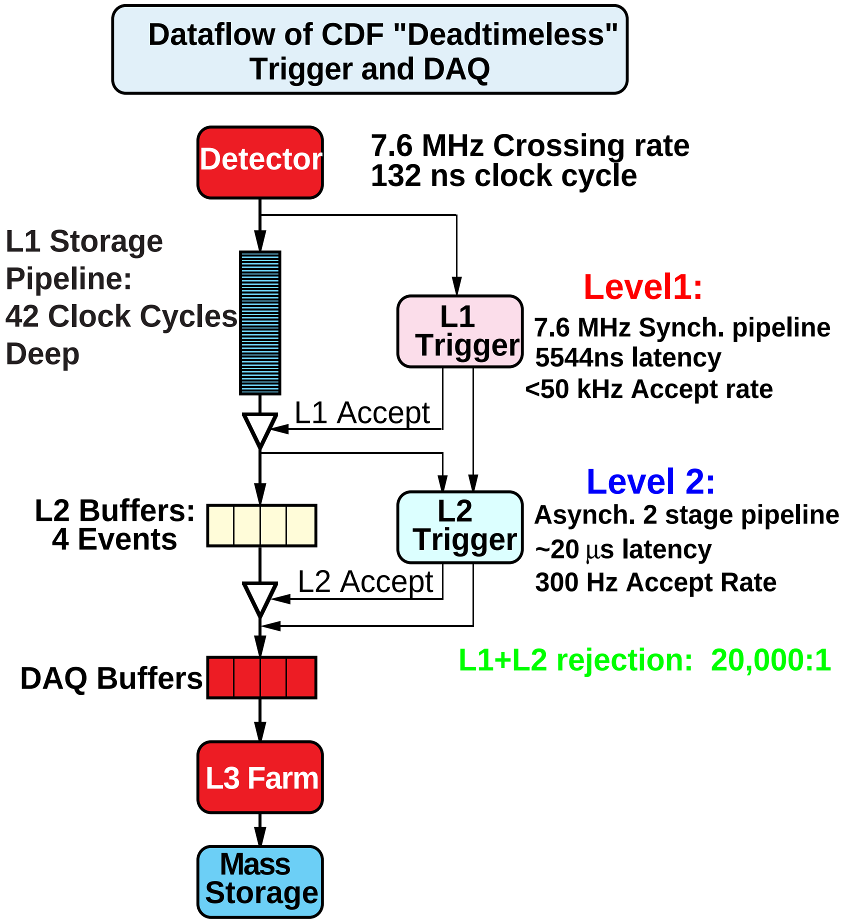
NO Silicon in NON standard trigger conditions w/o consent from pager carrier !

- regardless of what the expert says – they are experts of THEIR system, but (usually) NOT of the silicon
- They surely don't mind using a US$ 20 Mio device to debug theirs BUT do they really need the silicon to accomplish what they want ?
- Only situations where silicon can be included by default without pager carrier consent:
  - During 'normal' data taking with silicon biased, and TevMon GREEN signal
  - During quiet time for cosmics running (silicon biased), when it is made sure MCR does not inject beam into the machine without notifying us.

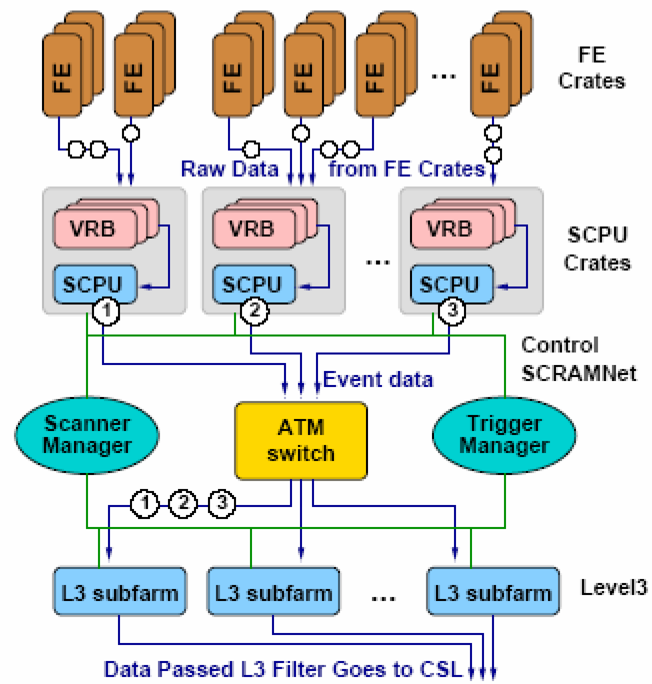
IF IN DOUBT: PAGE THE PAGER CARRIER OR SPL

- Usually the OpsManager was made aware of the request and has already consulted with Silicon people.

Review of Trigger/DAQ

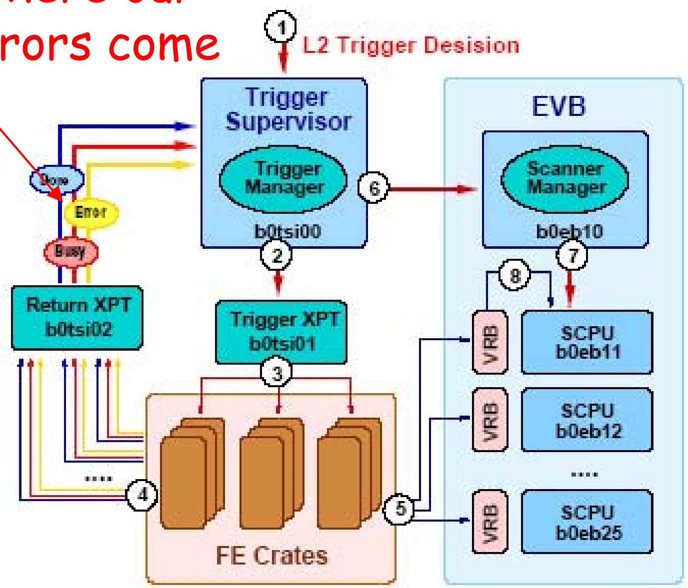


- Detector 'samples' data every 132 ns
- 'Samples' are stored in a pipeline buffer
- Data is sent to the Level1 trigger
- trigger decides within trigger latency of ~4µs
- If event is kept, data is stored again in L2 buffer still in front end awaiting L2 decision within ~20 µs (**not** for silicon)
- If L2 Accept, copy data into DAQ buffer and further up the chain.



DAQ Overview (from Ray Culbertson)

This is where our fatal errors come from



The L2 Trigger sends the trigger decision to the Trigger Supervisor (TS).

The L2 trigger decision is sent to the FE crates through the trigger cross point.

When the trigger decision is received in the FE crate, the VME Readout Controller (VRC) sends back a DONE signal to the TS via the return cross point indicating that it is ready to receive the next trigger decision.

We have an SRC

Not Si: Silicon reads out to VRBs on L1

Data from the FE cards (TDCs, ADMEMs...) is formatted and sent via the TRACER to the VME Readout Buffers VRBs.

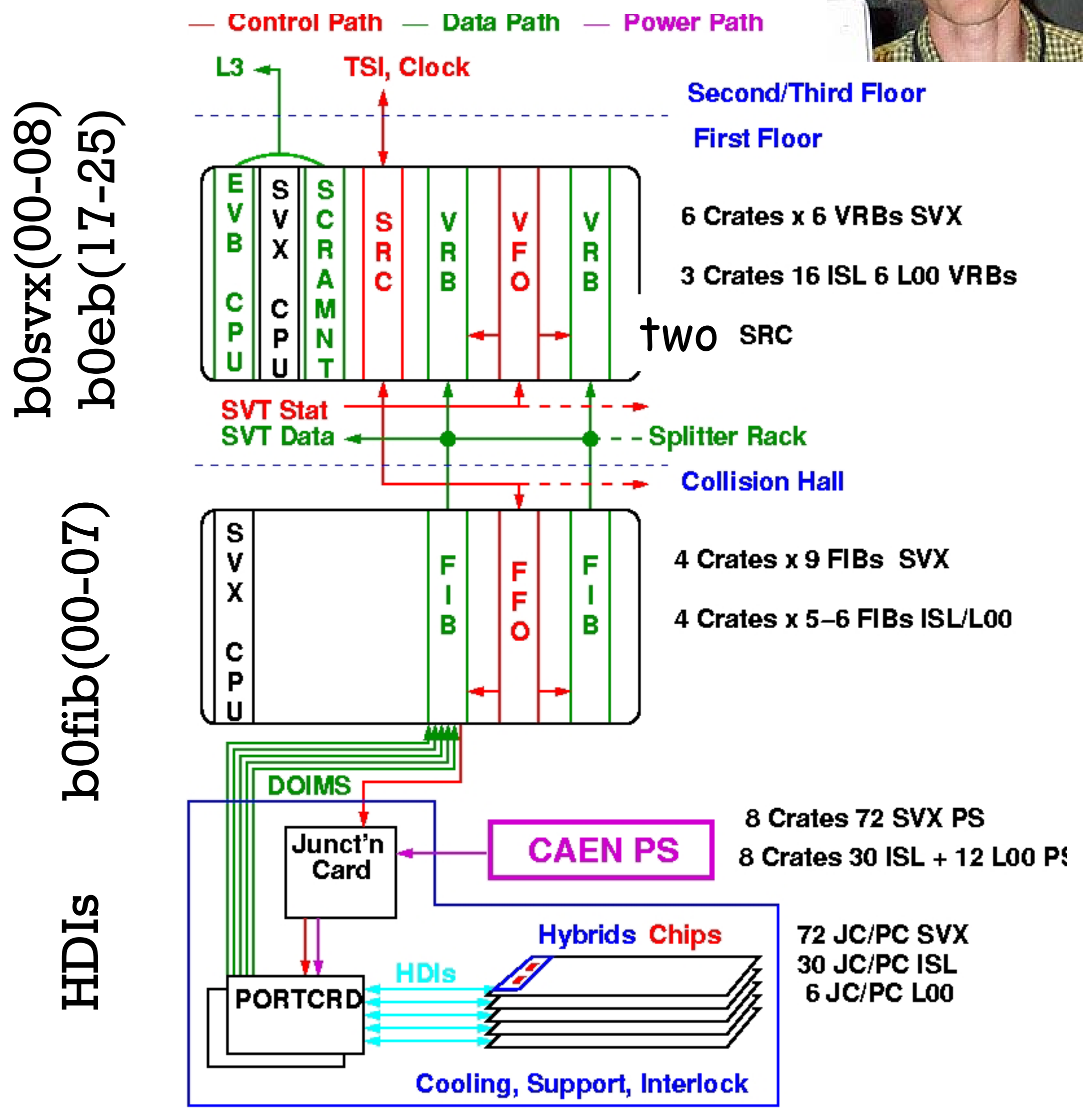
If there is not enough space to write out the event to the VRB a BUSY signal is sent back to the TS so that the TS does not issue another trigger which leads to busy deadtime.

→ If the busy is not deasserted in time we can get a Busy Timeout causing the run to halt.

This guy knows it all =>

Silicon from the DAQ Perspective

- **Silicon is different**
  - 17 crates, but TWO **SRCs** which talk to TSI
    - All **BUSY**, **DONE**, and **ERROR** timeouts come from them ***though problem may be elsewhere***
    - SRCs live in b0svx02 and b0svx06
  - Due to SVT, Si reads out to VRBs after L1A (not L2A)
    - VRBs are crucial
    - L1DONE signal to TS indicating data transferred to VRB
  - CPUs play role only in initialization and monitoring
  - b0svx** crates shared with EVB – you can't shepherd them and if you reboot them by other means, you have to clean the EVB!



Silicon Readout Controller (SRC) from Steve Nahn

- Controls what is going on when in the Silicon
  - Interfaces with the TSI for Trigger and Readout
  - Manages which buffers are in use, which are free, etc.
  - Responsible for "keeping the chip happy"
- Sends to FIBs and VRBs
  - Signals: Like L1A, PRD2 –Signals go "straight through"

Fiber Interface Board and friends (from Steve Nahn)

- Fib Crate contains
  - FFO: Conduit from SRC to *n* FIBs
    - Takes Glink optical signal converts it to 20 bits of backplane signal including Clock, Commands, Signals
    - Sends "Status" back to SRC
      - Used for Resonance detection
  - FIB: Mr Middle Man
    - Initializes Chips by VME
    - 10 x 8 bit DOIM input → 4 x 20 bit Glink output to SVT and VRB
    - Interprets SRC Commands via its Sequencer
    - Processes the Data read out

Bulk Memory – The VME Readout Board (From Steve Nahn)

- VRB crate contains
  - VFO: SRC $\leftrightarrow$ VRB communication
  - VRB (running CDF SVX firmware)
    - Receives Data from FIB, store in (1 of max 12) buffers selected by SRC
    - Processes 16 bit wide data up to output (64 bits)
    - During readout $\rightarrow$ other VME access interferes

Silicon DAQ Runtime Errors

Run Time Errors: `Halt-Recover-Run` is first line of defense.

If anything persists, page Si pager. You might first see an error condition from a silicon crate – get more information on `HALT` when Si crates query all boards and find potential problems

i.e. `Silicon Timeout:BUSY- Slots: 10:fa00 12:fa20…`

```
NOTE: on HALT will see also messages like
(MLE) b0svx04:Messenger:1:51:03 PM->Silicon Resonator:Sl 18 Ch 1 -> e481:
   Bytes: 00064
(MLE)b0svx00:Messenger:1:51:03 PM->Silicon Resonator:Sl 20 Ch 6 -> e0b1:
   Bytes: 00040
```

These are only meaningful if a resonance was detected, see below.

- `Done TO`: Data did not get sent to the VRB. Very rare, usually means a VRB is bad. Error handler
- `L1 Done TO`: TS has lost count of how many free buffers in Si Chips. Exceedingly rare.
- `Busy TO`: Means VRB has no more space for events. **Exceedingly common** , as **EVB** stops when any data corruption is detected **anywhere** (normally **NOT** in a Silicon crate) and the Silicon VRBs fill up first. Find data corruption and page responsible group.
- `Done TO from TRIGGER_SCALERS_00 Rate too high`: L1A rate too high to safely operate silicon. Usually trigger table is corrupt or there's a hot trigger. Page Trigger, look at TrigMon.

Silicon DAQ Runtime Errors (cont'd)

- `SRC Fatal Error:` Data taking has stopped due to a serious error condition – HRR should help.

  current SRC firmware ailment:

  `SRC Fatal Error:Sl 5 L2A w/o L1A`

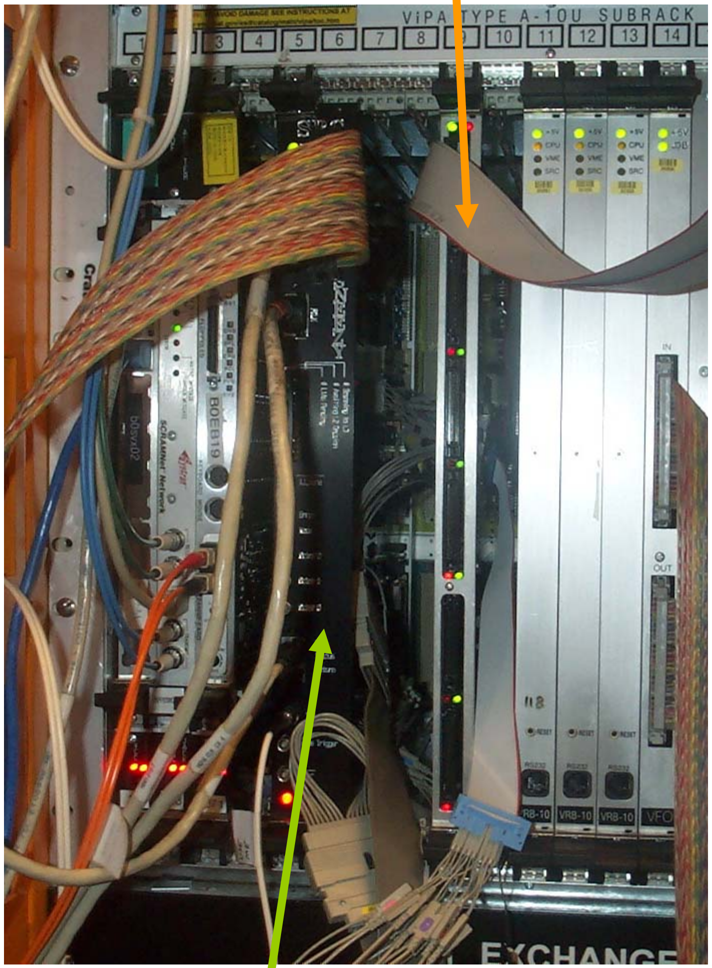
  depending on data taking conditions we might want to be paged immediately, else HRR out of it and make a note

- `SRC Fatal Error:` SL 5 Resonance detected: A resonance condition was detected which is potentially harmful for the silicon. Note that only b0svx02 and b0turns RED first, then on HALT you will receive the error message.

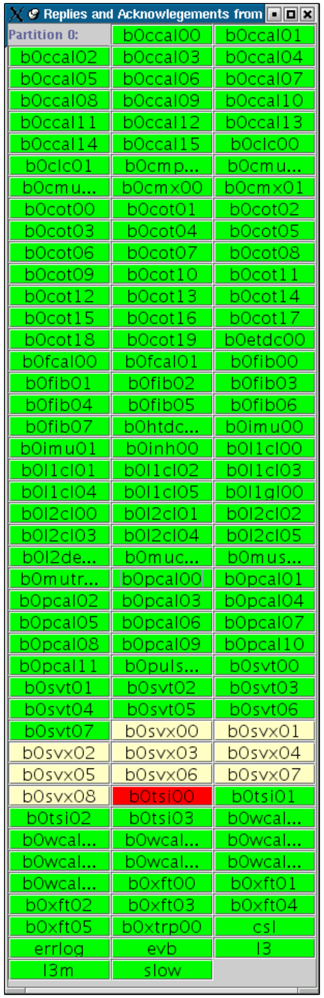
  Additional information on HALT

  ```
  (MLE) b0svx04:Messenger:1:51:03 PM->Silicon
     Resonator:Sl 18 Ch 1 -> e481: Bytes: 00064
  (MLE)b0svx00:Messenger:1:51:03 PM->Silicon
     Resonator:Sl 20 Ch 6 -> e0b1: Bytes: 00040
  ```

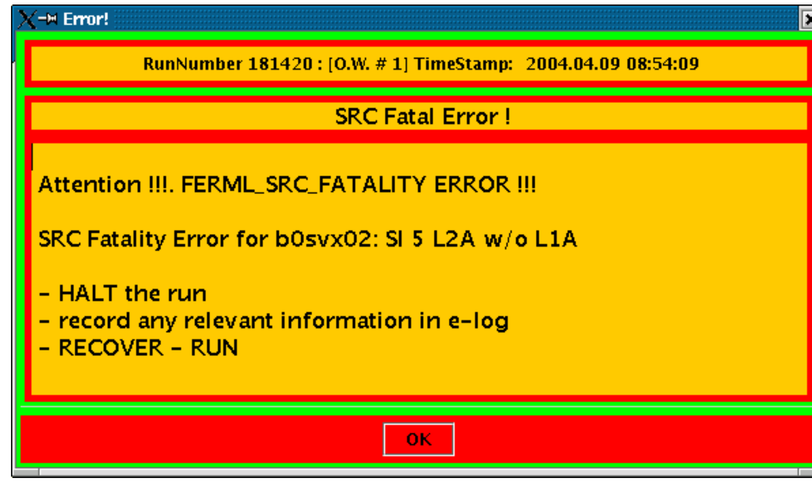
- RECOVER and RUN once, on 2^{nd} time page silicon.



SRC L2 w/o L1 FATAL Error



- Recently, L2 w/o L1 bites us on ACTIVATE
- Error will be reported by b0tsi00 rather than b0svx02
- You can only abort the run in this case, upon which you will get



- Call the main pager carrier and/or SRC expert to have the error reset.
- Remember: Detailed information will be only provided on HALT (if available) or ABORT.
- Detailed instructions see Sat April 10th Eve elog
- Always consult the errorlog file ~cdfdaq/errorlog

Summary

- (Si) DAQ is complicated business – but it pays in efficiency to understand
- Understand the meaning of the different states START, IDLE, READY, HALT and the respective transitions
  - In particular don't RESET if you don't have to
- Always consult the error logger/error log file
- Keep in mind unless you are in HALT you might only get half the story – ABORT is the same from this point of view.